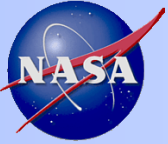
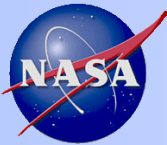


Overview of CADRe




Background

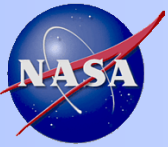
- NASA previously had no current repository of historical project data (programmatic, cost, and technical data)
- Cost risks have not been well documented or not explicitly addressed in most project estimates
- History of projects not recorded so we have difficulty learning from the past
- Quality of cost estimates vary from project to project.
- When cost data are collected, they are not disseminated or made available to others



2004 GAO Report Findings-Genesis for CADRe

- 1992 GAO study of NASA cost analysis
 - 29 projects; median cost growth 77%
- 2004 GAO study
 - 27 projects; median cost growth 13%
- 2004 GAO recommendations
 - Develop an integrated plan including
 - Guidance for rebaselining
 - Enforced use of EVM
 - Staff and support for cost-estimating and EVM
 - Establish standard LCCE framework
 - Include full life cycle
 - Use a standard WBS that encompasses both in-house and contractor efforts
 - Use a Cost Analysis Requirements Description (CARD)
 - Develop Independent Cost Estimates (ICEs) at each milestone
 - Use cost risk assessments
 - Prohibit projects from proceeding through the review and approval process without above

GAO	<div>United States General Accounting Office</div> <div>Report to the Subcommittee on Space and Aeronautics, Committee on Science, House of Representatives</div>
May 2004	NASA
DRAFT	<div>Lack of Disciplined Cost-Estimating Processes Undermines NASA's Ability to Effectively Manage Its Programs</div> <div>Hinders</div>
<div>Notice:</div> <div>This draft is restricted to official use only.</div>	<div>This draft report is being provided to obtain advance review and comment. It has not been fully reviewed within GAO and is subject to revision.</div> <div>Recipients of this draft must not, under any circumstances, show or release its contents for other than official review and comment. It must be safeguarded to prevent improper disclosure. This draft and all copies remain the property of, and must be returned on demand to, the General Accounting Office.</div>
GAO-04-642	<div> G A O</div> <div>Accountability • Integrity • Reliability</div>



CADRe Definition

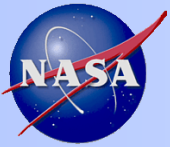
CADRe (Cost Analysis Data Requirement) is a 3 part document that describes a NASA project at each milestone, contains key technical parameters, and captures the estimated and actual costs in a WBS structure. The CADRe provides historical record of cost, schedule, and technical project attributes so that estimators can better estimate future analogous projects.



- [illegible]

- [illegible]

5



Why Are CADRes Needed?

- Provides historical record of cost, schedule, and technical project attributes so that estimators can better estimate future similar projects
- Describes project mission and approach that facilitates understanding
 - Contains objective technical data that tend to drive costs
- Required by NPR 7120.5



Part A Example

Provides Descriptive Info of S/C and Payloads, etc

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A.1.1 System Overview & Launch

The Deep Impact spacecraft, shown below in Figure 3, will be launched in January 2004 and will approach the target comet, 9P/Tempel 1, in early July 2005 (see Figure 4, below). The impactor is both a smart and simple spacecraft, and it is carried to the comet by the flyby spacecraft and released 24 hours before impact. Optical navigation is used on both the flyby S/C to start the impactor on a precise course, and on the impactor, for small corrections to achieve an impact on the sunlit side of the nucleus. Imaging data from the impactor camera provide the first "up-close and personal" look at a comet nucleus. This data plus that from the flyby S/C payload are recorded, with selected images relayed in near-real time to Earth.¹⁰

The impact occurs early in the evening of Saturday July 2/4, 2005, U.S. time, with approach images available for television. The impact will be visible in small telescopes at planetary star parties. Working with a distinguished Science Team, Dr. Michael A'Hearn, a prominent comet scientist from the University of Maryland, leads the mission as its Principal Investigator. The flight hardware and ground systems are developed by Ball Aerospace and Technology Corp (BATC) and the Jet Propulsion Laboratory (JPL). This development team has a proven record of successful collaborations, including the recent 1-year development of the QuikSCAT spacecraft and payload.¹¹

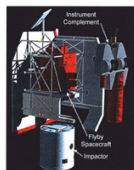


Figure 3 Primary Components of the Deep Impact Flight System (Exploded View)¹²

The mission is implemented with a flyby S/C and a smart impactor. The impactor is a simple, battery-powered spacecraft that operates independently of the flyby S/C for only the one day between separation and impact. Extensive commonality in the electronics and instrumentation between the impactor and the flyby S/C minimizes cost and increases reliability. Mission requirements are well understood and easily satisfied within subsystem designs of resources. Examples are mission duration (10 months, simplifies reliability), solar range (0.62 to 1.55 AU, power and thermal design), Earth range (0.99 AU at encounter, telecom and DSN resources), and a simple trajectory (CCD not above hydrazine propulsion).¹³

Mission Design

DI is launched by the reliable Delta II launch vehicle (7925H version); Figure 5, below, shows the launch configuration. The simple ballistic orbit from Earth to the comet includes launch in

¹⁰ Executive Summary, Deep Impact CSR, 26 March 1999, p. 2.
¹¹ Executive Summary, Deep Impact CSR, 26 March 1999, p. 3-1.
¹² Executive Summary, Deep Impact CSR, 26 March 1999, p. 3-11.
¹³ Executive Summary, Deep Impact CSR, 26 March 1999, p. 3-12.

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System Overview

Subsystem Description

Payload Description

Project Management

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A.2 Subsystem Description

The Deep Impact Flight System (FS) is shown in its free-flight configuration in Figure 9. Figure 10 shows the system decomposed into its three elements:¹⁴

1. The Flyby Spacecraft carries DI's instrument complement and impactor to the vicinity of the nucleus, releases the impactor, relays impactor data back to Earth, supports the instruments as they image the impact and the resulting crater, and then transmits the nucleus and crater data to Earth.
2. The Impactor, following its release from the flyby S/C, guides itself to impact with the nucleus surface, delivering 26 gigajoules of kinetic energy to excavate a crater 120 m wide and 28 m deep. During its brief flight into the comet, the impactor acquires and transmits to the flyby S/C high-resolution images of the nucleus. The impactor also serves as the launch system interface to the multi-S/C-impactor-instrument stack.
3. DI's Instrument Complement guides the flyby S/C and impactor and acquires the primary science remote sensing data that will be studied to meet science objectives. DI's very substantial baseline crater excavation margin allows flexibility to remove impactor copper to eliminate any risk from flight system mass growth.

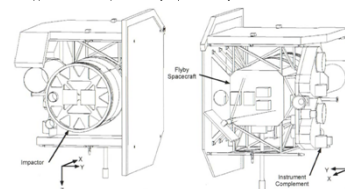


Figure 9 'Impactor First' Flight System Configuration¹⁵

For each subsystem in this section (A.2), the flyby S/C will be described first, followed by the impactor S/C. The instrument complement will be described in section A.3.

The flyby S/C design minimizes risk by incorporating 50% flight-proven hardware at the box level, eliminating single point failures through redundancy; requiring no deployment; and providing large performance margins. In addition, the flyby S/C configuration provides comprehensive protection from cometary debris.¹⁶

The impactor's short 24-hour mission life, combined with its architectural simplicity, provides very high operational reliability. Development cost and risk are minimized by using common hardware and software designs in the flyby S/C and the impactor.¹⁷

¹⁴ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-25.

¹⁵ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-9.

¹⁶ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-11.

¹⁷ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-12.

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3.3 Impactor Target Sensor (ITS)

The telescope for the Impactor Target Sensor (shown in Figure 52) is identical to the MRI telescope. Similarly, the CCDs and associated electronics are identical to those for MRI and MRI-5000 beam splitter directs the light from the telescope to the two identical CCDs to provide a redundantly redundant design. The CCDs are cooled to 240 K by means of an isolated radiative plate with a clear view of cold space. Flexible thermal links connect the radiative plate to the CCD mounting structures. Since the primary task of the ITS is to supply targeting information to the impactor S/C, two star trackers and an Inertial Reference Unit (IRU) are mounted directly to the ITS structure to reduce possible co-alignment errors due to thermal gradients.¹⁸

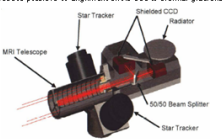


Figure 52: Impactor Targeting Sensor¹⁹

3.4 Common Electronics

Figure 53, below, is a schematic of the common electronics for the CCD detector supporting the exposed instruments as well as the common architecture for all electronics. The detector electronics include a timing generator, clock drivers, and a set of analog-to-digital processing units. The eight channels for the CCD (two for the 1500-line FPA) all function synchronously and all outputs are multiplexed to a parallel bus that links directly to the mass memory or are fed into a high-in-flight (HIF) buffer for transfer to the SCU. All timing, mechanism control, and data outputs are coordinated by an Essential Services Node (ESN) micro-controller, which consists of a multi-chip module with a 690000 processor.²⁰

Using the pre-encounter and encounter, selected images, pre-determined by the SCU, will be transferred to the SCU via a dedicated RS-422 interface, controlled by the ESN to the SCU. The RS-422 interface is backed up by the MIL-STD-1553 bus, but a much reduced transfer rate. These images constitute the baseline data set and are backed up by a dedicated non-volatile mass memory, an EDMA-3.²¹

The EDMA-3, produced by Spectrum Astro, features 8.2 Gbytes (84 Gbits) of storage space. Each unit has two independently accessible, counter-rotating disk drives, each capable of 4.1 Gbytes of storage, equivalent to 11,000 full (16-bit) CCD images, and 77,000 re-binned 16 spectra. Both MRI and MRI-5000 have an EDMA-3, one drive for each FPA. This substantial storage capability not only allows for full backup of the baseline data but also allows for a significant enhancement to the science return in the form of a supplemental data set. The image sequencing will fill the drives to ~90% of their capacity; this data will be available after encounter.²²

¹⁸ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-35.

¹⁹ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-31.

²⁰ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-35.

²¹ Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-35.

²² Technical Approach, Deep Impact CSR, 26 March 1999, p. 3-35.

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Use Only

which gives each core PET the maximum product consistent with their requirements, manages itself but monitors and reports to an engineering is crucial in assuring that the responsive to science goals. A mission n engineer (MSE), has members from each optimization across the entire project (see

ed by project element managers (PEMs) and their assigned deliverables on time and on used by Ball on QuikSCAT is the model for EM is assigned technical, cost, and schedule reserves are based on allocations for the solution with the DMT.²⁴

somes the project manager, and the science n to acquire and process the data. Phase E

5 and Figure 67. Critical dates, funded slack we in Table 22, Table 23, and Table 24.

Overnight Board (UM, JPL, Ball)
Liaison to ST-4 / Other Comet Missions
Science Team

Program Control / Resource
Mission Assurance / Safety
Mission System Eng

Mission Operations
Manager
A. Taormina
(JPL)

Launch
Services
(KSC)

Mission Operations Team
Flight System Team
Mission Ops Services
(CMO)

Instruments
System Integration and Test
Launch Support and
Mission Operations

University of Maryland
JPL
KSC
BALL

Figure 54: Organizational Structure for Phase A-B-C/D²⁵

²³ Management Plan, Deep Impact CSR, 26 March 1999, pp. 4-2 to 4-3.
²⁴ Management Plan, Deep Impact CSR, 26 March 1999, p. 4-3.
²⁵ Management Plan, Deep Impact CSR, 26 March 1999, p. 4-3.

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Shows the Technical Data (Mass, Power)

[illegible]

System Level Tables

Payload Level Tables

Summary Tables

SYSTEM SUMMARY TABLE

	CBE Mass	CBE Power	CBE Power	CBE Power
	W/Contingency	W/Contingency	W/Contingency	W/Contingency
Payload Mass		75.3 kg	100.4 kg	75.9 g
Instrument 1 (HR)	45.9 kg	45.9 kg	45.9 kg	45.9 kg
Instrument 2 (IMR)	34.6 kg	34.6 kg	34.6 kg	34.6 kg
Instrument 3 (ITS)	21.5 kg	21.5 kg	21.5 kg	21.5 kg
Impactor S/C Dry Mass	475.8 kg	468.4 kg	468.4 kg	103.6 g
Structure & Mechanisms	350.2 kg	349.2 kg	349.2 kg	0.0 g
Thermal	21.5 kg	21.5 kg	21.5 kg	0.0 g
Electrical Power Subsystem	26.5 kg	26.5 kg	26.5 kg	2.6 g
Guidance, Navigation & Control	7.2 kg	7.2 kg	7.2 kg	0.0 g
Propulsion & Attitude	32.1 kg	32.1 kg	32.1 kg	5.0 g
Telecommunications	5.8 kg	6.4 kg	5.8 kg	0.0 g
Command and Data Handling	19.3 kg	19.3 kg	19.3 kg	0.0 g
High S/C Dry Mass	323.3 kg	308.4 kg	308.4 kg	278.5 g
Structure & Mechanisms	174.4 kg	176.0 kg	176.0 kg	5.0 g
Thermal	19.3 kg	19.3 kg	19.3 kg	0.0 g
Electrical Power Subsystem	50.5 kg	57.7 kg	50.5 kg	17.3 g
Guidance, Navigation & Control	21.1 kg	20.3 kg	20.3 kg	48.3 g
Propulsion & Attitude	24.5 kg	25.8 kg	24.5 kg	0.0 g
Telecommunications	20.2 kg	22.9 kg	20.2 kg	193.4 g
Command and Data Handling	24.6 kg	24.6 kg	24.6 kg	22.0 g
Propellant	71.1 kg	62.4 kg	62.4 kg	22.0 g
Impactor Propellant & Pressurant	8.2 kg	11.8 kg	8.2 kg	0.0 g
Target Propellant & Pressurant	63.0 kg	50.6 kg	54.2 kg	0.0 g
Total (Dry)	888.5 kg	845.2 kg	845.2 kg	458.0 g
Total (Wet)	959.6 kg	907.6 kg	907.6 kg	458.0 g
LV Capability	1144.3 kg	1144.3 kg	1144.3 kg	1144.3 kg

KEY TECHNICAL PARAMETERS

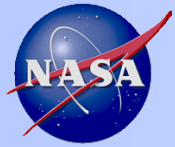
WBS Name	Component	Value
System	Human Factor	No
	Destruction	Contact Temporal
	Type of Craft	Piloted/Impersonal
	Launch Date	1972/2004
	Average Payload Power (V)	54.6
	CHMTC Method	2-airc Surveillance
	Pointing Accuracy	17 arcsec
	Pointing Knowledge	17 arcsec
	Data Storage	8.4 Gbytes
	Number of Instruments	3
	Downlink Mode	X-Band
	Downlink Data Rate	100 - 85,600 bps
	Uplink Mode	X-Band
Structures & Mechanisms	Uplink Data Rate	8 - 2,000 bps
	Launch Vehicle	Delta II (7325)H
	Launch Configuration/Shift/Thrust Material	GRPE
	Insulation Type	MLI
Electrical Power & Distribution	Solar Cell Type	GaAs/Ga
	Battery Type	18-Ah (SPV)
	Battery Power Output	16-Ah
	Monopropellant Thrusters Thrust	2.2 N (0.5 lbf) 35.5
Propulsion Subsystem	Monopropellant Thrusters Thrust	2.2 N (0.5 lbf) 35.5
	Transmit/Receive Band	X-Band
	Payload/pointing SAC Crosslink Band	UHF
Communications Subsystem	Antenna Type	LOA, MDA, MHP
	Solid State Recorder Memory Size	3.4 Gbytes
CADI Subsystem		



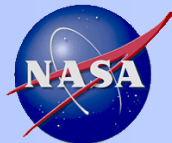
Part C Example

Shows Cost data by WBS

Shows Cost data by WBS



CADRe Timelines



When are CADRes Required?

Program Phases		Formulation		Implementation			
Flight Projects Life Cycle Phases	Pre-Phase A: Concept Studies	Phase A: Concept Development SRR/MDR	Phase B: Preliminary Design	Phase C: Detailed Design CDR	Phase D: Fabrication, Assembly & Test Launch	Phase E: Operations & Sustainment	Phase F: Disposal
Traditional Waterfall Development or Directed Missions		①	①a	② ▼ ②a	▼ ③	④	⑤
AO-Driven Projects	Down Select Step 1 ▼	Select Step 2 ▼ ①	② ▼ CR ②a	▼ ③	④	⑤	

Legend



Mission Decision Review/ICR



All parts of CADRe due 30 days after site review



CADRe update, if necessary



CADRe delivered; based on Concept Study Report (CSR) and winning proposal



All parts of CADRe due 30 days after site review



CADRe update, if necessary



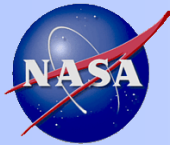
Update as necessary 30 days after CDR



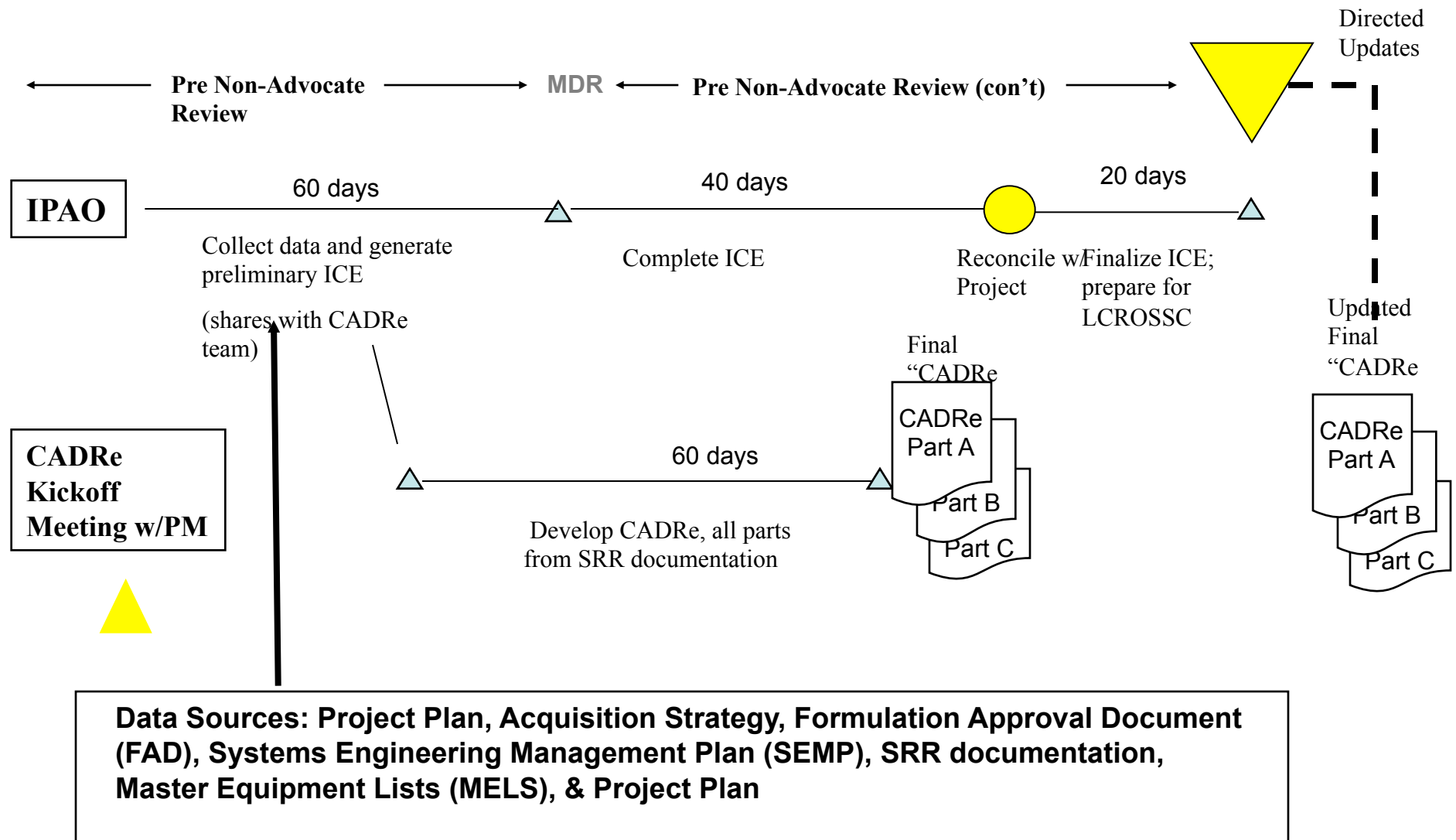
CADRe, All Parts 90 days after launch, as built or as deployed configuration



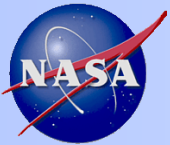
CADRe, Part C only during last year of planned project life



Timeline for 1st CADRe



*IPAO agrees to place collected data on PBMA



Source Documents for CADRe

Part A. Descriptive Information

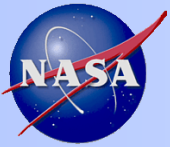
- Project Plan
- Architecture Description Document
- Acquisition Plan
- Project Implementation Plan
- System Engineering Plan
- Risk Mitigation Plan
- Integrated Design Definition Documents (Constellation)
- Milestone Review Briefing Packages (SDR, PDR, CDR etc)
- Concept Study Report/Proposal (if applicable)
- Concept of Operations
- Integrated Master Schedule
- Integrated Test Plan
- Monthly Status Reports
- Any Instrument specific MDR, CDR, PDR packages
- ATLO Plan (used later in the project)
- Mission Readiness Review (used later in the project)
- Pre Environmental Readiness Review (used later in the project)
- Launch Readiness Review (used later in the project)

Part B. Technical Data

- Master Equipment Lists
- Project Schedules
- Mass Property Reports
- Power Budget Summary Report
- Software Design Reports
- Milestone Briefing Packages/Documentation

Part C. Life Cycle Cost Estimate

- Project Cost Estimate by WBS
- WBS Dictionary
- POP costing details
- 533 reports (used later in the project)
- EVM reports (used later in the project)



What CADRe Does... and Does Not Do

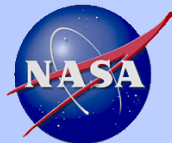
CADRe Does

- Provide a detailed snapshot of the project at each milestone.
- Presents the known details of the project.
- Uses existing project documents.
- Captures technical programmatic, cost, schedule detail.
- Track and explain changes from previous milestone.
- Actually helps the PM record in a formal agency document events that occurred during the project (both internal & external).

CADRe Does Not

- Operate as a project monitoring tool.
- Provide any evaluations, opinions, or recommendations of the project.
- Create another independent estimate of the project.
- Force the project to create new or additional documentation to support CADRe.
- Cause hardship on project time and resources.

(PA&E/CAD pays for and coordinates all CADRes developed across NASA)



CADRes are being loaded into ONCE database

Completed CADRes

ONCE Database

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A.1.1 System Overview & Launch

The Deep Impact spacecraft, shown below in Figure 3, will be launched in January 2004 and will approach the target comet, 98TJ12, in early July 2005 (see Figure 4 below). The impactor is both a small and simple spacecraft and is carried to the comet by the Flyby spacecraft and released 24 hours before impact. Critical investigations to be conducted by the Flyby S/C, to allow the impactor on a precise course, and on the impactor, to small cometary features to achieve an impact on the south pole of the nucleus. Impact data from the impactor camera provides the first 'top view' and 'onset' look at a comet nucleus. The data also that from the Flyby S/C payload are recorded, with selected images relayed in near real-time to Earth.

The impact occurs early in the evening of Saturday July 30th, 2005. U.S. time with approach images available for broadcast. The impact will be visible in small telescopes at latitudes at least 20°N. Following with a designated science team, to be named (likely, a scientific team) from the University of Maryland, lead the mission as its Principal Investigator. The Flyby S/C and ground system are developed by the Ames Research Center (ARC) and the Jet Propulsion Laboratory (JPL). This development team has a proven record of successful collaborations, including the recent 5-year development of the Cassini spacecraft and payload.¹¹

Figure 3 Primary Components of the Deep Impact Flight System (Simplified View)¹²

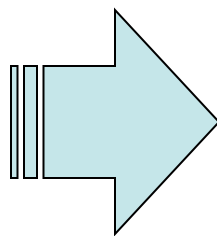
The mission is implemented with a Flyby S/C and a small impactor. The impactor is a simple, battery-powered spacecraft that operates independently of the Flyby S/C for one day before separation and impact. Extensive communication in the electronic and autonomous operation between the impactor and the Flyby S/C, mission cost and mission reliability. Mission parameters are well understood and easily adjusted within substantial margin of resources. Examples are mission duration (10 months, simplified reliability) (range 9.5 to 1.65 Au, power and thermal design), Earth range (300 AU of mission), launch and S/C recovery, and a simple trajectory (CDO into above hydride propulsion).¹³

Mission Design

It is launched by the reliable Delta II launch vehicle (7020P version). Figure 5, below, shows the launch configuration. The simple ballast orbit from Earth to the comet includes launch in

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11 Executive Summary, Deep Impact CDR, 28 March 1998, p. 2.
12 Executive Summary, Deep Impact CDR, 28 March 1998, p. 2.
13 Executive Summary, Deep Impact CDR, 28 March 1998, p. 2.

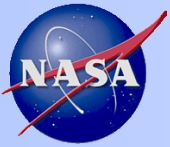


ONE NASA COST ENGINEERING (ONCE)
Insight and Management of CADRe Data

Project: Aquarius Event: SRR

CADRe Status

Part A	Part B	Part C
Description	Description	Description
A.1 System Description	System Level Parameters	Project WBS and Life Cycle Cost Estimate
A.2 Subsystem Description	Payload Parameters	Project WBS Dictionary
A.3 Package Description	Rover Hardware Parameters	NASA WBS and Life Cycle Cost Estimate
A.4 Project Level Description	Entry Descent Level Hardware Parameters	NASA WBS Dictionary
A.5 Significant Changes since Previous CADRe Submission	Spacecraft Hardware Parameters	Basis of Estimate
Summary of Part B - Technical Data	Software Metrics	Detailed Element WBS Costs
Summary of Part C - Project WBS and Cost	Mission Operations System (MOS) and Ground Data Systems Parameters	Build Project WBS
	Summary Tables	



ONCE Design Features

ONCE Database

- Web-based
- Controlled access
- Automated CADRe Search & Query

Mimics CADRe templates: Parts A, B and C

- Fast source document upload for developers
- Reporting features to quickly pull needed data

ONE NASA COST ENGINEERING (ONCE)
Insight and Management of CADRe Data

CADRe Status Screen

Drag a column header here to group by that column.

Project	Event	Center	Developer	Status	Comments
ACRIMSAT	SRR	APL		Planned FY 07	
ACRIMSAT	PDR	APL		Planned FY 07	
ACRIMSAT	CDR	HQ		Planned FY 07	
ACRIMSAT	LRD	HQ		Planned FY 07	
ACRIMSAT	EOM	JPL	JPL	Planned FY 07	CADRe Plus
AIM	SRR	GSFC	SAIC	Planned FY 06	
AIM	PDR	GSFC	SAIC	In Process	
AIM	CDR	GSFC	SAIC	In Process	
AIM	LRD	GSFC	SAIC	Planned FY 07	Not started yet
AIM	EOM	GSFC	SAIC	Planned FY 08	
Aquarius	SRR	JPL	Aero	Completed	Need to make sure we get comments BJR / CDR delayed to Sep

use of authorized users only. Item monitoring, including the user system may subject you to.

ONE NASA COST ENGINEERING (ONCE)
Insight and Management of CADRe Data

Project: Aquarius Event: SRR

CADRe Status

Part A

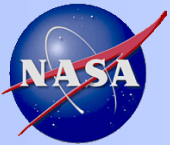
Description
A.1 System Description
A.2 Subsystem Description
A.3 Payload Description
A.4 Project Level Description
A.5 Significant Changes since Previous CADRe Submission
Summary of Part B - Technical Data
Summary of Part C - Project WBS and Costs

Part B

Description	Status
System Level Parameters	
Payload Parameters	
Rover Hardware Parameters	
Entry Descent Level Hardware Parameters	
Spacecraft Hardware Parameters	
Software Metrics	
Mission Operations System (MOS) and Ground Data Systems Parameters	
Summary Tables	

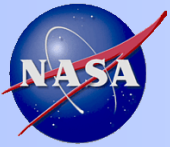
Part C

Description	Status
Project WBS and Life Cycle Cost Estimate	
Project WBS Dictionary	
NASA WBS and Life Cycle Cost Estimate	
NASA WBS Dictionary	
Basis of Estimate	
Detailed Element WBS Costs	
Build Project WBS	



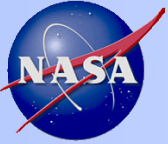
How do I Access CADRes?

- Developed CADRes to date are all contained on NSCKN. Go to link and apply for an account:
<https://nsckn.nasa.gov/>
- For help contact Eric Plumer for access.
- Access Rules
 - HQ personnel will have access to all CADRe data
 - NASA center personnel will have access to
 - Only their own pre-launch CADRe data
 - All CADRes after missions have been launched



How do I Access ONCE database?

- Contact Eric Plumer for access.
- <https://oncedata.com>
- On login screen download access form
- Fill out form and email/fax to Eric Plumer
- Anyone with a valid NASA Identity in IDMAX can have access.



Points of Contact

- **NASA**

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